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MEMO ON FEASIBILITY
OF SUBMARINE OIL TANKERS
(For Arctic Transport)

(Compiled by William H. Patterson)

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ARCTIC ISLANDS and MAINLAND:

Assuming that discovery in the Arctic Islands and on the mainland (where tributory to the Arctic Ocean) of prolific reservoirs of oil and gas, will ultimately justify present geological enthusiasm, then transport of oil and gas becomes a major economic factor

TRANSPORT: Progress in the development of ice-breakers by Canada, and to a greater degree by Russia (such as the huge atomic-powered "Lenin") demonstrates that surface navigation can be maintained despite its obvious obstacles. A body of opinion, however, is that the submarine cargo vessel, designed to take advantage of the "protective" covering of the Polar ice could provide more economic Arctic Ocean transport for oil and liquified natural gas, as well as other cargoes the specific gravity of which is comparable to that of sea-water ballast.

MARKETS: Upon discovery of prolific and low-cost Arctic oil and gas, producers would doubtless, for a long term market, look toward the coasts of North America, to Europe and to Japan, and such neighbouring Far East areas as are presently net importers.

Some comparisons of the sub-ice Polar route distances as against other oil routes in statute miles are as follows:-

Southampton, England, from Persian Gulf via Suez - 8000 miles, and from Melville Island (Canadian Arctic) - 3300 miles.

Japan from Persian Gulf - 7900 miles, while from Melville Island via Bering Strait - 3600 miles.

The U. S Eastern Seaboard is also somewhat over 3000 miles from the Arctic Sedimentary Basin

The Arctic Basin via the Polar route is half the distance of Venezuela from the European markets.

Shortened distances favour the Polar route for general commerce of suitable nature. The following quotations dealing with the Polar route are from the reports of the officers of the U. S. Nuclear Submarine "Nautilus", as printed in Life Magazine February 1959, p. 60: "Commercial submarines .... would shave great distances... Tokyo to London, normally 11,200 miles ... . Polar passage ..... 6,500 miles.. .. Seattle to Oslo is 9,300 miles, but an Arctic sub would travel only 6,100 miles. The Arctic Ocean may be easier to negotiate in dead of winter than in spring or summer."

"It has gradually become apparent, that the Polar Sea lies in a deep basin, its floor broken only by occasional under-water hills and ledges, and one long under-water mountain range."

Thus evidence builds up that the Arctic Ocean affords a true Northwest Passage through safe submarine routes.

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COMPARATIVE TANKER RATES

It is well known that surface tanker tariffs are lower than pipeline rates. One apparently reliable ratio for surface tanker rates against big-inch pipeline rates is given as 4/5ths of a cent per barrel per 100 statute miles as against 3 cents per barrel by pipeline.

It is convincingly contended that when cargo is available and the submarine cargo vessel is built in numbers, then the submarine oil tanker will be more economic than its surface counterpart. Commander Woodward of the Mitchell Company is quoted as stating that when three submarine tankers can be built the cost of each would be halved.

Some factors favourable to the submarine are its ability, by sailing below wave action, to cruise faster or with less power, and without having to take avoiding action in respect to ice-bergs. Use of nuclear power eliminates fuel bunker space.

Atomic Submarines Now in Use

Wide publicity has been given to the Polar sub-ice exploits of the U.S.S. nuclear submarines Nautilus and Skate. Now we read in the Calgary Albertan, February 12/60: "Sub reaches North Pole. Washington (U.P.I.) Third U.S. atomic powered submarine reached the North Pole .... after cruising 2,744 miles under the Arctic icepack in (for) 14 days and 21 hours."

Then there is the story that another submarine cruised 2000 miles without surfacing, powered by hydrogen peroxide. If this bunker saving fuel could power buzz bombs, why not submarine oil tankers?

Quoting from the officers of the Nautilus we read that the "Nautilus cruised more than 20 miles per hour (1839 miles) beneath the Polar ice. Deeper channels (i.e. deeper than to the Pacific) to the Atlantic serve the whole Archipelago. Down below it is always calm .... no vibration .... no fog, storms or sea-sickness. Barrow Submarine Canyon drops abruptly to 5700 ft. at the western end of the Trans-Arctic Seaway, in which the Nautilus and Skate sailed in safe water with depths from 6000 to 13,000 feet.... Thus was reported 'the opening of a trade route for rapid voyages between the great Pacific and Atlantic oceans - a truly practicable Northwest Passage.'"

The opinion that the submarine tanker is feasible is shared by Canadian technical men. For example Alex Hemstock, Research Engineer, Imperial Oil, speaking to Rotary at Edmonton, as reported by Radio Station C.F.C.N., Calgary, April 2/59, said: "Science's greatest contribution to the (Arctic) transportation problem will be in the field of under-sea craft. The vessels will mean that the whole Arctic will have access to the shipping lanes of the world ...."

Atomic Submarine Developments

Research and experiment into atomic commercial submarines is reported to be proceeding in several countries - by Mitsubishi in Japan, by Mitchell Engineering in England, by Krupps in Germany, and by the Maritime Administration, Department of Commerce, in the U.S.A.

The largest suggested cargo submarine is a 100,000 tonner envisioned by the Japanese. Possibly the most practical, efficient and economic example could be the 20,000 ton, 20 knot model under consideration by the Maritime Administration. Mitchell's model is a 50,000 tonner.

"English experiments advanced to test models of an 80,000 ton capacity submarine tanker with a speed up to 50 knots." (Oilweek, Feb. 27/59, p. 3) "Southampton, England. (Reuters). British Industrialist, E. D. Mitchell, left .....

for canada.... to discuss building a giant atomic powered submarine.... would increase trade with northern Canada by cruising under Hudson's Bay when ice-bound...50,000 tons ..... 600 feet long." (News item, Vancouver Sun, April 10/59).

"The Maritime Administration, (of the U. S. Department of Commerce) believes that 40 knot submarine tankers are a possibility. To attain that speed the Sub would require far less power than would its surface counterpart." The foregoing is quoted from "The Arctic as a Sea Route of the Future" by Commander William R.Anderson, U.S.N., Capt. U.S.S. Nautilus, p. 21, Jan. 1959, National Geographic Magazine.

"U. S Federal Maritime Administration has contracted for a study of possible nuclear powered submarine tanker .....20,000 to 40,000 tons carrying capacity .... believes 40 knots a possibility. The Japanese .... studying 100,000 ton design." (Reports of the officers of the U.S.S. Nuclear Submarine Nautilus, as published in the January, 1959 edition of the National Geographic.)

"Subs can punch through the North Polar icecap. Nuclear subs will be able to manoeuver effectively under Arctic ice regardless of the season. The Navy announced Friday that the U.S.S. Nuclear Submarine Skate had completed a twelve day voyage under the icecap." (John Averill, (A.P.) Vanc. Sun, March 27/59)

The following news items from the Calgary Herald, June 27/59 again indicates intention to develop cargo submarines to use the Polar route. "Essen (Nana) - Krupp will build a diving chamber to be used by Auguste Piccard in experiments for the U. S. Navy intended to extend vastly operating depths for nuclear submarines. . . . will conduct diving experiments at 15,000 feet .... Krupp's interest ... is enhanced by widespread German interest in cargo submarines which could use the Polar route to reduce distances."

Possibly escape of radiation will in time impose limitations on the extent to which nuclear power will be permitted, but it would seem that the use having first priority would be for the powering of commercial submarines to ply the Northwest Passage, which could be the shipping boon sought by mariners for generations.

The rapidly increasing number of nuclear power plants for naval submarines, for ice-breakers and other commercial vessels will quickly reduce building costs. Examples of the nuclear trend are the ice-breakers "Lenin" and the Maritime Administration's "N. S Savannah", which is a world first. The ship was launched July 21/59 at Camden, N. J. The picture of this ship appeared in the Vancouver Sun of July 22/59 in a news story captioned "First Atom Ship Forerunner of Maritime Automation Era." Following are excerpts:- "Washington, (NEA) ..... (The atom-powered 21,000 ton N. S. Savannah ..... could spark recovery of U. S. merchant fleets so that they can again meet foreign competition on the high seas. How could this be when the Savannah cost $31 million, and a conventional ship of the same size costs but $20 million? ..... Shipping men think automation will cut down costs enough for U. S. ships to meet foreign competition.... she will run at 20 knots, go three years without re-fueling.... A number of shipping companies want to build atomic tankers. . . The Maritime Administration has almost completed plans for such an atomic tanker. The Maritime Administration is now looking even further ahead. It has already had preliminary research done on an atomic submarine tanker." Other news items stated that the Savannah would be chartered to private industry after governmental experimentation is completed.

ATOMIC POWER ECONOMICS:

An atomic power plant in a ship, with steam going directly into turbines can be compared in economics to an atomic power plant on land. The following is from the Financial Post of June 27/59, p. 13:- "Nuclear Plant to compete in cost with $8 ton coal. Ottawa (Staff) - Canada's first full-scale nuclear power plant, which has been given a green light by the Government, is aimed to achieve costs low enough to compete with a modern coal-fired plant using coal at $8 a ton. That means less than five mills per kilowatt hour. .. Output is to be 200,000 Kwh... . AECL has been eager to go ahead

primarily to give early proof to the world of its reactors using natural uranium and heavy water. (FP May 16, 1959). Preliminary cost estimates made more than a year ago, put total energy costs at 5.78 mills per kwh, of which 3.18 represents the fixed charges on capital."

"Spokesmen say that as speeds and powers are increased beyond the range now used for modern ships, nuclear propulsion will undoubtedly become even more attractive and competitive because bunkering requirements for a commercial oil-fired plant increase with the square of the speed." That quotation is from an article entitled "'A' Power at Best in Superships" by T. P McGuinness in the Journal of Commerce (New York), (Int'l Edition), May 16, 1959, p. 16. Also from that article; "Economies of size seem destined to play a large role in the application of atomic power to merchant ships, the maritime industry believes." "..... a conventional vessel... might require only 4,000 barrels ..... to complete a New York - Bremerhaven run at 20 knots, but it would need 8,000 barrels to make the voyage at 30 knots..."

"Oil-fired ships may eventually find it prohibitive to sacrifice payload space for the higher speeds; no sacrifice is necessary with nuclear ships. ... shipping men believe they (nuclear ships) will find their earliest and greatest commercial application on long voyages where quick turn-around is desirable and where higher speeds and greater powers will result in expanded services - tankers, dry cargo bulk carriers and passenger ships.

"Space-wise, the requirements of the two kinds of power plants are about the same the advantage, if any, going to the atom."

Then on the question of reduced cost of atomic plants afloat compared with those on land, the article in part continues; "A tanker's payload - oil - scientists say makes an excellent shield. All of these possibilities constitute savings over land-based reactors which generally require immense thickness of lead and concrete, heavy complicated engineering for re-cooling systems and huge supporting foundations."

The article pointed out that the sea itself will aid nuclear plant in shielding against radiation; in regard to cooling; and in the matter of supporting the tremendous weight of the reactor The article further states that Richard P Godwin, Nuclear Projects Officer, Maritime Administration, thinks American shipyards will undertake the new ships.

SUMMARIES OF TWO FEASIBILITY REPORTS - MITCHELL REPORT

Mitchell Engineering Limited of London, England, reports that "As a result of the study (commissioned to Saunders-Roe Ltd.), it has been established that the building of a nuclear powered submarine cargo vessel is a feasible proposition with present day materials and knowledge, and that such a submarine could operate under the ice to trade with specific terminals in the Canadian north during their 'closed' season."

The Mitchell report continues: "The following were among the reasons for establishing the feasibility of building such a submarine:-

(a) The absence of wave making resistance when the submarine is fully submerged at her operating depth. This means that less delivered horsepower is required to drive the submarine at speeds of 20 knots than would be required to drive a surface vessel of similar dead weight carrying capacity at equivalent speeds. The faster the speed the greater is the submarine's advantage.

(b) The ability to serve ports that are closed to surface vessels by ice during the winter seasons; (c) The ability to avoid dangers, delays and discomforts experienced by surface ships in bad weather; and (e) The higher speeds will insure quicker delivery of urgently required goods."

The Mitchell company points out, however, that the ideal cargo is one of approximately the same specific gravity as the salt water which must be used as ballast when the submarine is travelling light, and that cargoes must be limited in bulk so that the pressure resisting cargo hatches can be kept as small as possible. Here again oil would be a suitable cargo.

Rather deep harbours are required because of the somewhat deep draught of the submarine. This draught feature is also important in fitting out basins, dry docks, etc. (Note below the comparatively shallow draught attained in the Maritime Administration's designs).

The Mitchell report continues: "In the U.K. the light surfaced draught is restricted to less than 35 feet which means a maximum displacement of 50,000 tons." Then "The obvious cargo was a liquid one, but a study of a submarine oil tanker has already been carried out by the Japanese."

"9. Knowing Canada's growing interest in her Northwest Territories and, particularly, in the iron ore deposits in Ungava, it was decided to examine the carriage of iron ore from the protected deep water area of Diana Bay to the United Kingdom. If the design and operation of a submarine to carry a 'difficult' cargo such as iron ore was proved feasible it could be assumed that designs for the carriage of other 'easier' cargoes would also be feasible."

"10. Size and Shape From an economic point of view the larger the submarine the better, but, as is mentioned above, size is restricted to a light draught of less than 35 feet, the minimum depth of the most suitable fitting-out basin in the U.K."

"11. Because of this, and after extensive tank tests and hydrodynamic calculations, a submarine of the following dimensions was chosen:-

Displacement	50,000 tons	Deadweight	28,000 tons
Overall length	607 feet	Overall beam	72 feet
Surface draught	59 feet	Light draught	33 feet"

"13. Diving Depth In order to avoid any surface wave resistance the submarine should manoeuvre at a depth slightly greater than 2.5 times her diameter, which is nearly 200 feet. In order to allow a margin of depth oscillation an operating depth of 300 feet was chosen with a maximum diving depth of 600 feet."

"14. Machinery The power source is a Mitchell 150 M.W. (thermal) Boiling Water Reactor. This is housed, together with the steam separators, circulating pumps, reheaters, auxiliary steam generators, and feed water and dump tanks, in a cylindrical containment compartment. The steam pipe to the high pressure turbine leaves the containment compartment through a valve which is monitored for radioactivity. This valve shuts automatically and also shuts down the reactor in the event of a serious rise in radioactivity."

"15. The main machinery consists of one high pressure and two low pressure turbines driving a single 25 foot diameter propeller through locked-train reduction gearing. The design and construction of the machinery would be by Fairfield Engineering Co. Ltd. in conjunction with Mitchell Engineering Ltd."

"16. The delivered horse power is 50,000 at 120 r.p.m. which will give a speed, at operating depth, of 25.5 knots."

"17. The main propulsion machinery absorbs approximately 129 M.W. at full load leaving 21 M.W. for auxiliaries."

"27. Cargo Handling The iron ore carrier under examination has been designed to carry 28,000 tons of iron ore and to be self-unloading at the rate of 4,000 tons per hour ....."

"29. As mentioned earlier a submarine freighter is limited as to the variety of cargo she can carry, but consideration has been given to some of these possible alternative cargoes:-

Oil	Bauxite
Aviation fuel	Grain
Liquid gas	Wood pulp
Fresh water	Cement
	Boxed goods (heavy density)

"31. Crew Until automation is introduced and perfected (the submarine of the future may be entirely unmanned) a crew of 50 has been suggested. Of these 17 would be deck crew, 21 engine room (including a nuclear engineer and instrument technician) and 12 cooks and stewards, etc."

"35. General Economics At the present time the capital cost of nuclear propulsion is very high when compared with similar powered conventional propulsion. For this reason a nuclear-powered submarine, such as is projected, would, at the moment, not prove as economical to run as a conventionally powered surface ship."

"36. However, nuclear 'know-how' is rapidly extending and the cost of nuclear power units and fuel is being proportionately reduced. Thus in, say, five to 10 years, large submarine bulk carriers, travelling at speeds of 30 plus knots, should be more economic than their equivalent surface sister ships."

"37. If this country (U.K.) wishes to maintain her lead in the maritime field of the future a nuclear-powered submarine merchant ship or fleet supply ship should be laid down as soon as possible so that Britain will have the experience and the men to build up her Underwater Merchant Navy in time to compete with world demand."

MARITIME ADMINISTRATION REPORT

The following information is taken from the Summary of the Feasibility Report prepared by the Electric Boat Division of General Dynamics Corporation for the Maritime Administration of the U.S. Department of Commerce. The report deals with nuclear-powered submarine tankers. The three hull forms investigated (one with a draught limitation) were designed to carry 20,000, 30,000, and 40,000 tons of cargo dead-weight, at speeds of 20, 30, and 40 knots submerged. The technical report is entitled "The Feasibility and Design of Nuclear Powered Submarine Tankers, dated December 1, 1958."

The report deals with purely commercial vessels. It did not deal with economics. "Refined petroleum products are lighter than water. The lightest cargo a submarine tanker might carry is 61° API gasoline, which weighs only 5/7 as much as sea water. Thus five tons of gasoline displaces seven tons of sea water; two tons of weight must be added in the form of structure or ballast to obtain neutral buoyancy. Consequently it is feasible to provide a structure safe for operation at depths as great as 1000 feet.

"With heavier cargoes - such as crude oil or bunker fuels - in the same submarine, the total weight can be made the same by simply carrying less cargo, or by removing some fixed lead or iron ballast.

"Another problem in submarine tanker design is the return trip in ballast. Since the volume is fixed by the outer envelope, and since the total weight must be kept constant, an amount of sea water ballast must be carried exactly equal to the weight of the cargo." (Page 2)

"It can be seen that a submarine design for heavy oil exclusively would require smaller and hence lighter variable cargo tanks. This saving in weight and volume, along with the removal of some fixed ballast, could be translated into a substantially greater cargo dead-weight in the same size submarine." (Page 3)

"Concerning speed, the submarine has the advantage over the surface ship that it does not generate waves, but it suffers from having a greater wetted surface. Thus, with optimum hull forms, two 20-knot designs - one a surface tanker, one a submarine tanker - show about the same power requirements. For high speeds, however, wave-making imposes increased power problems for the surface ship; although a higher-speed surface ship design could defer the upswing due to wave-making for a few more knots, the submarine curve becomes increasingly favorable at speeds above about 25 knots.

"As to hull form, in order for a submarine tanker to be accommodated in over half the major harbors in the United States, its surface draft in the full-load condition must be limited to 34 feet. A large submarine tanker designed for limited draft, then, must have a nearly rectangular cross-section of the outer hull." (Page 4)

"For a nuclear plant producing saturated steam, a 60,000-shp package was selected as a reasonable maximum; .... Allowing for engine room, reactor compartments, and radiation shielding, the resulting machinery space cylinder is about 35 feet in diameter and 165 feet long." (Page 5)

A submarine tanker, draught-limited, of a 20 knot design with rectangular cross-section, for cargo dead-weight of 20,000 tons is shown to have other statistics as follows:-

Surface displacement	35,730 tons
Submerged displacement	39,950 "
Loaded draft	34 feet
Length	530 "
Beam	85 "
Depth	38 "
Total power required	32,400 shp
No. of screws	2

Statistics for a submarine of the same design but to carry a cargo of a dead-weight of 30,000 tons shows statistics as follows:-

Surface displacement	53,130 tons
Submerged displacement	58,500 "
Loaded draft	34 feet
Length	675 "
Beam	90 "
Depth	40 "
Total power required	44,600 shp
No. of screws	2

As a guide, statistics are next set out of an unlimited draft submarine with circular cross-sections of 20-knot design:-

Cargo deadweight	20,000 tons
Surface displacement	35,140 "
Submerged displacement	38,660 "
Loaded draft	60 feet
Length	520 "
Maximum diameter	75 "
Total power required	17,000 shp
No. of screws	1

Thus it appears that the principal differences are much greater draft, and economy in the required power. Similar differences are noted in comparisons between larger draft-limited rectangular designs as against "body-of-revolution" (i.e. having circular mid-section) design. As a limitation as to draft seems unavoidable, the ship of rectangular mid-section seems to be the one which probably will first see construction and commercial use. "The excessive surface draft of each of these designs (body-of-revolution) could be reduced by limiting the maximum diameter and adding parallel body to the middle of the ship to maintain the volume. Since this would result in a longer and less favourable design, the power requirement would increase somewhat." (p.7)

"Draft-limited ships designed for 30 knots are not considered feasible. All would present complex tank arrangements coupled with excessively high power requirements or beam-depth ratios of questionable directional stability.

"The two unlimited-draft designs shown - for 20,000 and 30,000 tons of cargo - are considered feasible, although both would present some arrangement difficulties. A 40,000 ton design is not shown, since the power requirement and the beam-depth ratio are both excessive."

With further reference to 30-knot designs for cargo deadweights of 20,000, 30,000, and 40,000 tons, the Summary in part states: "No arrangement problems are anticipated in any of the designs shown below. Except for the large surface drafts - which could be reduced by adding parallel body - these designs are considered feasible." The loaded drafts are given as 62 feet, 70 feet and 77 feet respectively, and the power required 66,500 shp, 85,800 shp and 104,500 shp. (Page 8)

"Draft-limited ships designed to make 40 knots would require well in excess of 100,000 shp per shaft, which is outside the range of feasibility.

"Unlimited-draft rectangular-section ships of this speed are also not feasible, because of impossible machinery arrangements and excessive power requirements. Present power plant technology cannot overcome these problems.

"Submarine tankers of this speed must take advantage of a low-resistance body-of-revolution (circular) hull form, as shown in the above designs. .. The 40,000 ton design requires borderline power of 63,000 shp per shaft..... Thus the 40,000 ton, 40-knot ship - the largest of those considered - has a maximum diameter of 102 feet and draws about 80 feet of water in the loaded surface condition; it draws about 50 feet in the light condition.

"Therefore these optimum hull form ships are not practicable, particularly in the larger sizes since not only will it be necessary to load and discharge such ships off-shore, but also there are no existing dry docking facilities capable of taking a vessel drawing much over 40 feet of water

"Nevertheless, it is possible to redesign these hulls to obtain a compromise between power, draft and length to enable such ships to be dry docked."

The report then shows a modified version of the largest and fastest of these ships (Pages 16 and 17). Reference to these pages indicates that "the vessel selected by the Maritime Administration for further development was a modification of the largest and fastest vessl in the parametric series. This one was selected not with the idea that such a vessel is likely to be built within the near future, but rather to show the approximate upper limit of feasible speed and cargo deadweight within the scope of present day technology.

"In modifying this design a limitation of 60,000 shp per shaft was observed. This, coupled with the addition of parallel body necessary to reduce surface draft reduced the predicted speed to 37 knots. This ship could be accommodated in existing dry docks." (Page 16)

Statistics for this ship include the following:- (Page 17)

Cargo deadweight	41,565 tons
Surface displacment	91,903 "
Submerged displacement	101,000 "
Loaded draft	67 feet
Length	936 "
Maximum diameter	80 "
Total power required	240,000 shp
No. of screws	4

"CONCLUSIONS AND RECOMMENDATIONS: The following general conclusions about submarine tankers can be stated:-

1. In general submarine tankers limited to a surface draft of about 34 feet are feasible only for speeds up to about 20 to 25 knots. The high power required for faster ships makes it almost mandatory to use a more nearly optimum hull form to keep power and ship proportions within reasonable limits, and this requires deeper drafts. (2) The upper limit in speed with present power plant technology is in the vicinity of 40 knots - varying with cargo capacity - even with the hull having negligible form resistance

"More accurate information on the resistance of rectangular hull forms is needed. Model tests should be performed on such hulls so that more accurate estimates can be made of the power requirements and controllability of these hull forms." (Pages 18-19)

"The Most Conservative: The original contract for this study has been extended to include a more detailed study of the first designs shown on the preceding pages - that of the 20,000 ton, 20-knot rectangular hull with limited draft ..... For economy this design incorporates a single reactor and a single screw." Some statistics pertaining to this "most conservative" design are as follows:-

Cargo deadweight	21,189 tons
Surface displacement	38,791 tons
Submerged displacement	42,671 tons
Loaded draft	35 feet
Length	583 feet
Beam	80 feet
Depth	40 feet
Total power required	35,000 shp
No. of screws	1 "

(Page 21)

Thus the draught-limited submarine built with the economies possible when for transport of heavy oil exclusively, and designed for speeds up to 20 - 25 knots, submerged, is feasible. The reduction in cost as cargo submarines become required in numbers will speed the day when they will be accepted as "more economic than their equivalent surface sister ships."

CREWS FOR COMMERCIAL SUBMARINES

The only nuclear specialists required are, as above stated, one nuclear engineer and one instrument technician. It should be feasible to obtain such personnel in view of the great number of submarine crews trained by the various navies, and in view of the scientific minds now being mass produced by the universities of the world.

NAVIGATION DEVICES

Any difficulties of navigation seem to have been overcome, e.g. the accurate pin-point successes in the various long sub-ice cruises of the U.S. nuclear submarines. The under-ice navigational instruments include the fathometer - a sonar device which measures distances to the bottom; the echo finder which measures the distance to the ice above; the television camera which shows the passing ice formation; and the "inertial navigator (which) performs like a champion." (Nautilus Reports)

YEAR-ROUND HARBOURS

When oil cargoes become available harbours will be required at strategic points accessible from deep channels fingering among the Arctic Islands. These harbours should be kept free of ice and will need loading facilities. Such harbours and facilities appear to be feasible. A news story speaks of a "Polynia" system which was installed by the Navy at Thule, Greenland. This is a system of pipes laid on the harbour bottom and fanning out to cover the used portion of the harbour. "The Polynia system involves the laying of perforated pipes through which compressed air is ejected. The bubbling water resulting, prevents freeze-up and resultant damage to harbour installations." Information is that a similar system has been used at Great Bear Lake and in the St. Lawrence Seaway.

More evidence of the feasibility of ice-free harbours is the bill introduced by Sen. Wiley of Wisconsin which would "authorize the Corps (U.S. Corps of Engineers) .... to review the applicability of the de-icing methods developed by private concerns or governments to the Seaway and Great Lakes Region .... relative to the establishment of a de-icing system; .... study of the conditions and problems between areas now successfully utilizing de-icing methods. The fact that de-icing systems are used in harbours normally ice-bound throughout the winter in Canada and elsewhere is sufficient evidence that efforts to combat winter ice in the Great Lakes hold promise for the future." Senator Wiley added: "The method of de-icing systems that have been developed include the 'bubble' system, an under-water piping system in which compressed air moves through tiny holes to the surface, melting the ice .... and other methods." Calgary Herald, July 16/59.

It is stated that experts at Saunders-Roe, engaged on the Mitchell studies, believe that surfacing through the ice will be done with the assistance of steam or compressed air.

MAGNETIC LOADING

The following is quoted from a news item in the Calgary Herald, Aug. 11, 1959, datelined Resolute Bay (C.P.): "Atomic submarine tankers or icebreakers could travel to the site of the wells, and in the case of the submarines, a cable under the ice could be magnetically linked to the tanker. The submarine could be loaded and return to warmer waters without surfacing. Underwater plastic pipelines could be laid to a more accessible point from where the oil could be transported by an ordinary tanker."

PIPELINE GATHERING SYSTEM

A number of suggestions have been made for the laying of pipelines on the Islands and from island to island under the ice to bring production to suitable harbours. The Deputy Minister, Mr. H. G. Robertson, is quoted as having suggested such pipelines, although in that instance he had in mind a pipeline under the ice to an ice-free port. Examples of submarine pipelines are multiplying, including a short 10 inch line on the harbour bottom at Goose Bay, Labrador.

OFFSHORE SHIPMENT OF LIQUIFIED GAS

The following is quoted from a paper delivered by Carl O. Nickle, former Member of the Canadian Parliament and Calgary oil executive, on "The Future for Western Canada's Oil and Gas", delivered on April 23/59 to the Canadian Petroleum Tax Society at Calgary. "The recent successful transfer of Louisiana Natural Gas in form of liquid methane, via the experimental tanker 'Methane Pioneer' to Britain, has opened a new branch of the world petroleum industry .... Vice-Chairman, William R. Connole of the U.S. Federal Power Commission recently said: 'Every cost estimate I have seen concludes that natural gas from abroad can compete with pipeline gas in the densely populated coastal United States. The only question seems to be how much competition and how soon.' The same can be said for areas of Canada that can be served by tanker. A supply to Britain from a 500 million cubic feet daily gas liquification plant now proposed in Venezuela will presumably be the first large-scale application of the 'Liquified Methane' transport system. But, over the next few years, far broader application is now predicted."

Thus, it is believed that, assuming prolific production of gas in the great formations in the Canadian Arctic Islands, that gas could be exported commercially, and producers could anticipate such political action as might be necessary to protect the market in North America.

CONCLUSION -

Feasibility of Submarine Tankers

From the foregoing, and particularly from the feasibility summaries of Mitchell Engineering Ltd. and of the General Dynamics Corporation for the Maritime Administration, it is concluded that the transport by submarine tanker of crude oil and liquified gas from the Arctic Islands is feasible and would in due course become economic following prolific production of low-cost oil and gas. It also appears that when the oil and gas industry supplies the cargo the shipping industry will furnish the subs.

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